GPS based Track and Trace for Transparent and Sustainable Global Supply Chains

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Abstract

This paper provides an approach to use a continuous track and trace system based on GPS (Global Positioning System) technology in production networks. Therefore the ild institute for logistics and service management (FOM Essen, Germany) operates a new GPS based track and trace system with the name GPS.LAB. The results of the first trials with the existing system in the context of production planning and supply chain event management are presented in this paper. In a special example the GPS track and trace system is used to identify delays in an inbound logistics process of a groupage freight depot to show the influence of the delay on the routing of last-mile transports. This could be labelled as a last mile event routing (LMER) concept.

Keywords

GPS track & trace, production planning, logistics, Last Mile Event Routing

1   Introduction

In production alliances, where many different companies at separated regional production plants are in an economic relationship, several logistic activities have to be executed. Besides the physical flow of materials for procurement, production and distribution activities - which are in fact transport activities - much communication is necessary because several different players have to work together for achieving the common aim of added value [Meers, et al. 2010]. Therefore logistic service providers are an important part of the supply chain and have to fulfil many added value services, like e.g. assembling activities or coordination of transports. To secure the described cooperation, a high level of communication especially at supply chain interfaces is essential. Surveys underline the demand for more transparency as well as more security in supply chains and the cooperation with innovative logistics service providers who are able to provide these for customer and shipper [DB Schenker Laboratories 2009]. Especially in production networks, which nowadays have to be more flexible and variable, logistics activities are complex and new solutions are needed to tackle the safeguarding of logistics performance according to delivery times and service levels. A realization of the potentials of GPS based track and trace services in logistics can make sure that these challenges can be solved by using the functionality of these solutions for cargo transports [He, et al. 2009; Carlino, et al. 2009].

The consequence of tracking goods is the tracing of the routes of transport, so that a tour can be illustrated on a roadmap with the help of mapping software. Because of this presentation it is easier to understand complex transport chains, for example to divide a groupage freight tour into forerun, mainhaul and post-carriage distribution. Furthermore a specific hub and spoke structure of a logistics network or the delivery position on the last-mile can be considered. Moreover a real-time tracking of shipments makes it possible to estimate the arrival of goods in a production network with several locations more accurately by forecasting arrival times at the production site with the help of actual position and speed data, for example in a concurrent enterprising alliance [Brewer, et al. 1999]. So production planners get a better support to synchronise the delivery of material and preliminary products with the production scheduling and get a longer time period to reschedule the production if needed. In addition the storage of historic routes provides extra

information and supports future planning challenges. Moreover a track and trace system can be used in the context of *'supply chain event management'* (SCEM). Existing concepts basically focus - among other things - on real-time information [Klumpp, et al. 2010]. Thereby the task of such systems mostly lies in realizing data along a supply chain as a prerequisite for (semi-)automated management (decision) systems. Supply chain management (SCM) needs a smooth information flow for an efficient functionality within a delivery chain [Nissen 2002] and SCEM has to ensure a permanent monitoring of the material flow along the entire chain to make coordinated management action possible [Beckmann 2003].

This paper presents an approach to combine the above mentioned applications by using the potentials of GPS based track and trace systems for supporting transport planning processes in production networks with an example of last mile routing in a groupage freight carrier depot. Therefore the state-of-the-art of track and trace solutions in logistics practice and a concept draft for 'last mile event routing' (LMER) are presented.

2   Track and Trace in Logistics Practice

2.1   Current Methods and Solutions

Courier, express and parcel service providers offer software solutions to track parcels during the transport process. This is a standard service of almost all players in this logistic service market. Customers get an identification number which can be used to check the parcel's status on the LSP webpage. In this segment of standardized and restricted sizes and weights of shipments it is implemented with the help of barcodes and automatic scan devices. In groupage freight networks the implementation of track and trace solutions is more complicated because of the heterogeneity of shipped goods and often associated with more need of man power [Hillbrand, Schoech, 2007].

Beside barcoding the technology of RFID (Radio Frequency Identification) is also used in logistics practice. Therefore the shipment has to be tagged with a RFID transponder. The transponder can look like a label, a smart card or a plastic coin. They have to be read with RFID reader devices which can be installed at loading platforms, forklift trucks or warehouse gates. These readers can identify shipments with the help of information saved on the transponders together with additional information like weight, temperature or construction date. Disadvantages of the RFID technology are high investment costs and lacking data security [Wannenwetsch 2010].

Barcoding as well as RFID can only be used when the logistics network is equipped with barcode scanning devices or RFID reader installations. This is even more complicated if several subcontractors are organized in a supply chain because the technical equipment has to be installed in the whole network. Due to several different standards a continuous hardware integration and a consistent data collection is nearly impossible [Hillbrand, Schoech, 2007]. Furthermore both techniques only offer geographical positions when the tagged shipments are located near fixed reading installations. So the shipment is only tracked if it reaches pre-defined fixed positions. So these track and trace solutions can only be described as "event-monitoring" because it is still unknown what is happening between two reading points, identified are only loading, handling or delivery points. That is why these tracking solutions are categorized as *discrete* tracking solutions.

On the other hand *continuous* tracking solutions make it possible to localize the position at any time. One possibility is a tracking by using the technology of GSM, but this is not very common. GSM devices calculate the run-time to at least three radio signals to three GSM transceiver stations. Depending on the radio cell dimensions where the GSM device is located the accuracy of the position can vary from 100 m to 35 km [Hillbrand, Schoech, 2007]. This is understandably not feasible for logistics applications because of the high range of localization accuracy.

GPS tracking offers potential to close the described gap: The actual position is defined continuously by the use of GPS signals. GPS modules calculate the distances to a number of satellites - usually at least four satellites are necessary to determine the location accurately [He, et al. 2009]. The determined position can be transmitted in real-time with mobile data services like GPRS (general packet radio service) if the modules are equipped with such a mobile communication technology. For this reason the shipped goods can be localized anytime and with a satisfactory accuracy of a few meters. A GPS based track and trace solution can be categorized as continuous tracking [Hillbrand, Schoech, 2007]. The described techniques can be overviewed in figure 1.
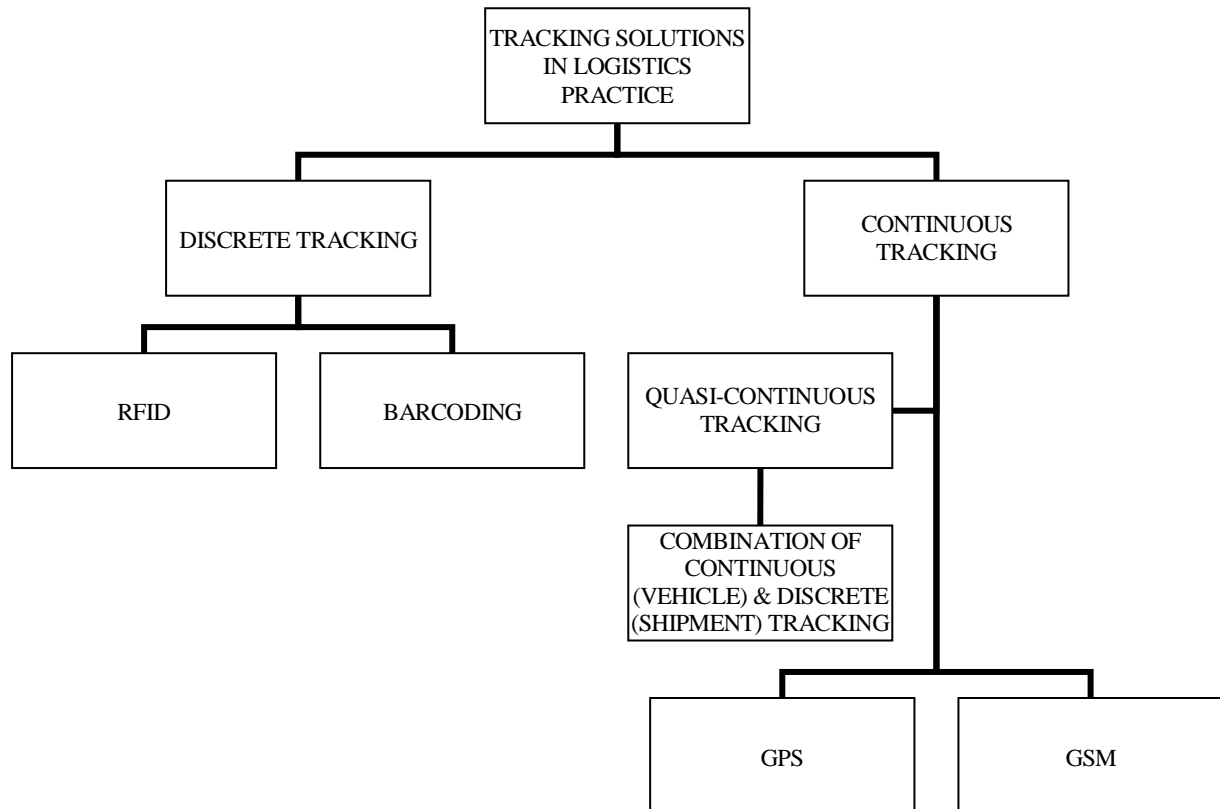
Figure 1: Categorization of Tracking Solutions in Logistics Practice

Furthermore the integration of GPS track and trace is independent from the IT infrastructure of the carrier. If the tracking modules are battery powered, the shipper can attach the GPS module to the shipment and can localize it on its own. Often this is possible with the help of a web application without special software. Even in big and open logistic networks the implementation of a GPS tracking is feasible if the tracking modules are mobile (requiring their own electricity supply, e.g. via batteries) because no extra infrastructure is needed.

There are lots of advantages of GPS tracking: For example a more transparent transport chain, an increasing delivery performance through faster problem identification, bottleneck identification in procurement logistics, more security for customers, more reliable data for tour or production planners, a faster reaction time in answering to delays and a growing customer satisfaction [Carlino, et al. 2009]. The criticism towards GPS tracking is the unreliability and the inaccuracy of the position data because GPS signals are often not available inside of containers or vehicles, in valleys or between high-rise buildings in inner cities because the modules are not able to connect to the required minimum of four satellites.

Today GPS shipment tracking is used for container monitoring of overseas transports and for the tracking of railway waggons. DB Schenker Rail has installed GPS devices at nearly 15,000 waggons to generate data of distance, service intervals or technical condition [Stopka 2009]. GPS tracking is also used in context of telematics services, e.g. fleet management. This major practical application of GPS tracking includes vehicle tracking with driver and vehicle data,

traffic information and on-board navigation. A GPS module is fixed in the vehicle and connected with on-board power [Wang, Potter, 2008].

In combination with a discrete tracking technology, this *'quasi-continuous'* tracking solution can be realized. Therefore the loading and unloading data has to be assigned to a vehicle. It has to be guaranteed that all vehicles used in the transport chain are equipped with an on-board tracking system. However the disadvantage is, that every vehicle which is used, needs a telematic device in contrast to GPS shipment tracking which is independent from specific vehicle [He, et al. 2009]. So the introduction and integration of a vehicle independent tracking is easier, leads to a higher level of flexibility but requires more tracking modules in the supply chain.

2.2 GPS.LAB at FOM ild

Since this year the ild institute for logistics and service management of FOM University of Applied Sciences, Essen/Germany, operates a GPS based track and trace system by AIS Advanced InfoData Systems GmbH, Ulm, partly funded by the Ministry of Innovation, Science, Research and Technology of the German State of North Rhine-Westphalia. To use the system and to analyse the results, a laboratory has been installed with the name GPS.LAB. One GPS tracking device has three major parts and is shown in figure 2:

1. A GPS black box as central part of the system. The module is equipped with a GPRS SIM card for transmitting the tracking data in real-time to a server. The transmission intervals can be set individually.

2. A high performance GPS antenna for strong receiving power to calculate the run-time of signals even with low signal strength or inside of trailers and containers. This was already tested and is working very stable inside steel boxes and trucks.

3. A high powered rechargeable battery for an independent powering of the GPS module. With a fully loaded battery the GPS module can be operated at least 72 hours.
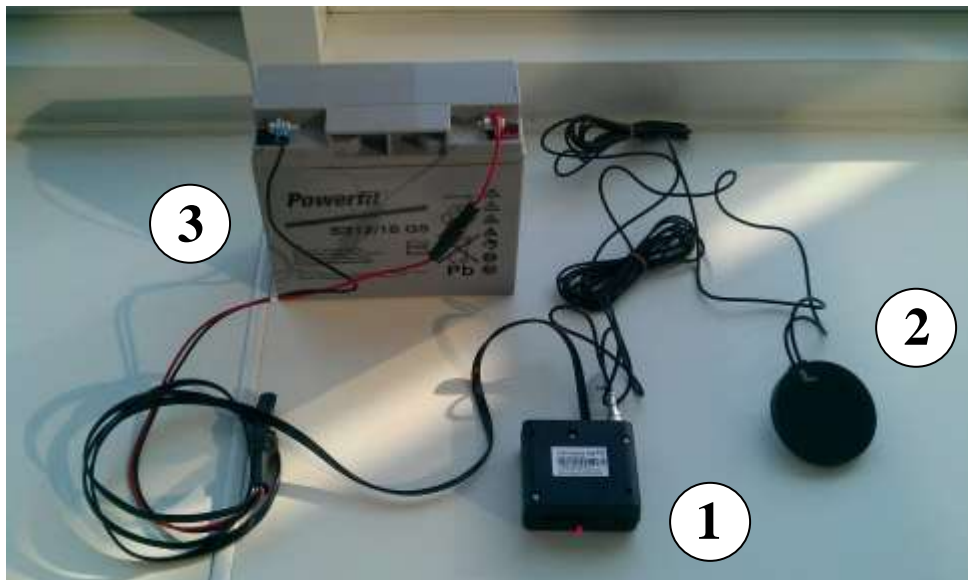

Figure 2: GPS Tracking Device with Black Box, Battery and Antenna

By reason of the above mentioned specifications the GPS.LAB makes it possible to track goods down to the level of pallets, cases, cartons or ideally items during the whole transport to retrace the logistic process in detail and to analyse the performance of supply chains. By the use of the software map & guide by PTV Planung Transport Verkehr AG, Karlsruhe, the GPS performance data can be mapped as a basis for further analysis and calculations. In fact, with the help of such a system logistic processes can be analysed well-founded as the data is verified by real transport and not by simulation.

3 Real-Time Last Mile Event Routing with GPS Input Data

3.1 Cargo Tracking in Production Processes

Stock-keeping in the shop floor has to be minimized to cut capital lockup in the form of material, which also supports a reduction of cycle time. Therefore it is necessary to safeguard just-in-time supply of material. In times of globalization, global supply chains with local separation of production plants with long transport routes in between are usual. An important problem is that a delay involves troubleshooting in production scheduling to avoid an interruption of the production process. A reliable flow of information is a basic requirement for today's dynamic and flexible production and logistics activities. In fact this should be included in anysoftware for supporting the production process [Meers, et al. 2010].

Telematics or cargo tracking in production alliances support the flow of information and improve the production system by reducing cycle-time, especially if tracking data is generated automatically and is transmitted in real-time to analyse data and to perform necessary actions in time [Brewer, et al. 1999]. Tracking data has to be continuously available at any time independent of transport mode and company boundaries, reliable and secure as well as easy to transmit and cost-efficient for the producer [Stopka 2009]. The problem of using a tracking system within a supply chain is the holistic integration of one system, especially if actors within the supply chain vary from time to time. So for these short-term multi-company networks an independent forwarder tracking solution is needed. By this idea the main difficulties of software integration could possibly be solved [Kärkkäinen, et al. 2004]. This could be a battery powered GPS tracking system like e.g. GPS.LAB.

Figure 3 shows a central production oriented view of the links before and after the production: Supplied material gets to the stock receipt, is handled and then delivered to the following supply chain member. A real-time tracking solution which is independent from forwarder or handling company supports the flow of information and material in the whole supply chain.
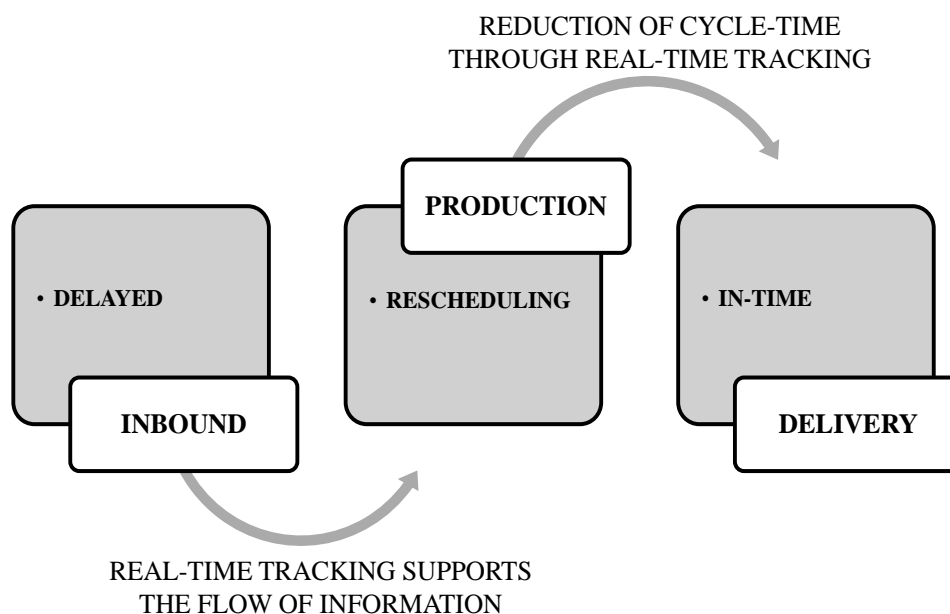

Figure 3: Additional Value of Real-Time Tracking in Production

The additional value of tracking in production networks is manifold: Location and identification of shipped goods is faster and easier to follow. With this information the expected arrival time at the shop floor can be calculated and combined with the production scheduling algorithm. The consequence may be a change of production schedule depending on the availability of materials in transit [Brewer, et al. 1999]. To sum up the advantages of continuous and independent

forwarder tracking, the response time in production scheduling due to events gets much faster so that the flexibility of production rises.

3.2 Influence of Delay in Delivery on Last Mile Event Routing in Logistics

The aim of the disposition or scheduling department is the utilization of last mile transports in the context of capacity and time. Therefore a standard production plan is configured with standard conditions of the production environment including the logistic processes. Any discrepancies of these standard conditions, for example in delivery, require specific actions to make the most of the production. Identification of discrepancies in the production environment today is often realized with an automatically actual-theoretical comparison of software systems used in the production environment [Wannenwetsch 2010].

In groupage freight depots a major problem is an early identification of delays of inbound transports. The consequence is a rescheduling of last-mile route planning, in fact a shipment is planned on another tour or a tour leaves the depot with delay. All activities have to be executed with high priority to avoid expensive delays. Normally the problem is not the effort of rescheduling but the identification of a delay, because the planning department is being reliant on a signal of the supplier or the forwarder. A tracking of cargo in production could safeguard this flow of information and reduce the period between incidence and information about a delay. This speed increase in information transmission makes it possible to optimize the re-planning of the last-mile transports so that the delay of deliveries to customers can be reduced. To show this, activities in a groupage freight depot are analysed as follows. This can also be applied in other production scheduling contexts.

The inbound long-distance transport displays the supply, the allocation of shipments to different last-mile routes, the machine scheduling, the last-mile delivery of shipments and the delivery to the following supply chain member comparable to figure 3. Last-mile transport routes with predefined delivery times and predefined areas are also known, so a standard allocation of shipments to these routes is given. The depot departure times of the last-mile transports are fixed because customers need to receive their shipments in time. So there is a buffer time which results from expected arrival times of inbound transports at the depot, planned departure times from the depot by given last-mile transports and a given handling time within the depot. If the difference between actual and planned arrival time is higher than the buffer time, a re-planning of the allocation to the last-mile routes is necessary.

3.3 Case Study

The influence of a delay on route planning for the last-mile transport was analysed in one night with the help of a groupage service provider. Therefore four long-distance inbound transports were tracked with GPS (from Munich, Schweinfurt, Hannover and Kassel on their way to a depot in Duisburg), so that actual arrival and departure times could be identified. The loaded shipments including destination (postal code and city), planned travelling times of the long-distance routes and a pre-defined allocation to last-mile routes according to the first three figures of the postal code with fix departure times can be taken as given, but do not describe the realistic procedure or allocation logic of the service provider.

Depot	Departure DU			Arrival DU		
	Plan	Actual	Delay	Plan	Actual	Delay
Munich	20:00	19:39	--------	05:00	04:57	--------
Schweinfurt	20:00	20:00	--------	04:00	04:02	--------
Hannover	17:30	18:25	00:55	05:00	03:12	--------
Kassel	18:00	18:05	00:05	04:30	05:25	00:55

Table 1: Travelling Data of Inbound Logistics

Table 1 shows the tracked inbound transports from April 27th to April 28th, 2011. The long-distance transport from central-hub at Kassel to the depot in Duisburg has been delayed about 55 minutes. The consequence was that 17 shipments did not reach their pre-defined last-mile vehicle in time, because the arrival time of 05:25 from Kassel plus an assumed handling time within the depot about 60 minutes leads to an earliest departure time at 06:25. So these 17 shipments cannot be delivered with the first two last-mile vehicles at 06:00 and 06:15. Nine shipments for postal code area 402xx have to be rescheduled on a later tour with departure at 08:00 from the depot and eight shipments for postal code area 41xxx have to be rescheduled from 06:15 to 08:15 departure.
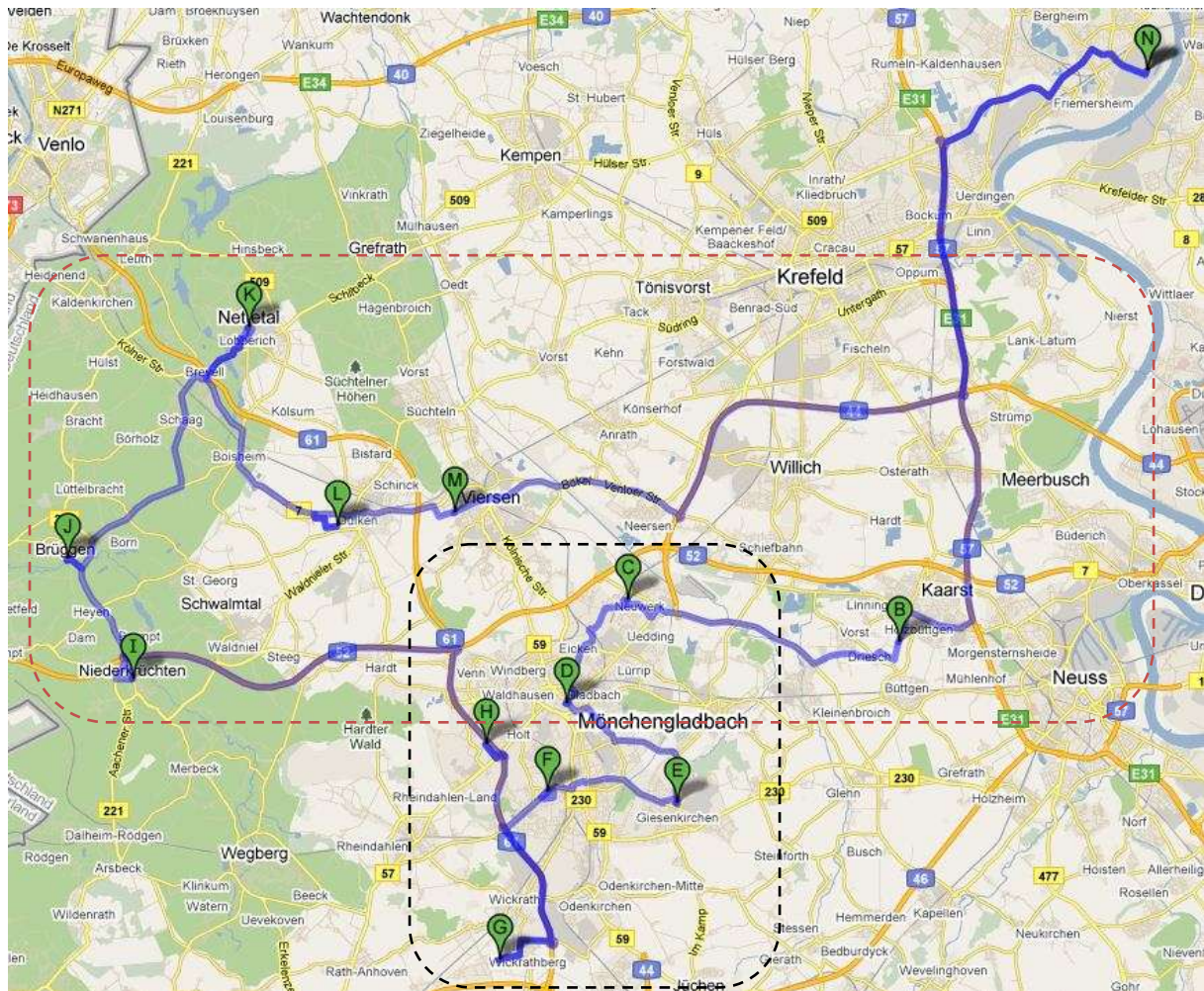

Figure 4: Impact of Delay on Route Planning in the Area of Mönchengladbach

Figure 4 shows the impact of delay on route planning on two exemplified displayed routes. Realistic would be, considering the pre-defined allocation logic, a planning of one tour for the city area of Möenchengladbach and another tour for the northern suburbs of the city (Viersen, Kaarst, etc.). Because of the inbound delay from Kassel some customers at the city of Mönchengladbach have to be served by the suburban-tour. This is necessary because the last-mile tour of Mönchengladbach has to leave the depot in time because of given time windows by customers. On the one hand this leads to longer distances and to higher delivery costs for the forwarder but on the other hand this safeguards the delivery in time for the customers. If the delay could be identified *before* the inbound transport arrives late at the depot by using GPS tracking data, it would be enough time to plan the last-mile routes directly with the information about delays so that no re-planning of the last-mile routes would be necessary.

4   Conclusion and Outlook

The sooner an information about a delay reaches the route planner the longer there is still time for rescheduling: If an information about a delay in the above described context is already known when the long-distance transport leaves the hub at Kassel, there is enough time for planning the last-mile traffic more efficient. So a continuous tracking system would support the last-mile route planning and could integrate information about the delay automatically in the route planning software so that troubleshooting activities could be reduced. This could be also applied on material supply and production scheduling in a modified way to support the flow of information about transport processes within production alliances.

Furthermore a continuous tracking leads to a more transparent logistics network, whether if it is a groupage freight network or a production network. The transport routes are visible and this indicates more security within the network. For the shipper a continuous tracking is also possible and confidence in the forwarder could rise.

In future research a model has to be designed wherein an event in terms of a delay would initiate a re-planning of delivery routes so that delays will automatically be considered by the route planning software.

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